The Influence of Oil and Gas Emissions On Ambient Non-Methane Hydrocarbons In Residential Areas

An interview with Dr Chelsea Thompson, Institute of Arctic and Alpine Research, University of Colorado, Boulder, USA

Dr Chelsea Thompson

Q: For anyone who has not read your paper (published November 14 2014, Elementa: Science of the Anthropocene), could you give an overview of the study you carried out, and the motivations behind it.

A: The primary focus of this particular study was to assess average ambient levels of non-methane hydrocarbons (also referred to more generally as volatile organic compounds, or VOCs) that residents living near oil and natural gas (O&NG) production operations are exposed to at their homes. Several air quality studies have been conducted in recent years within the Denver-Julesburg Basin, however, these have been located at more rural sites. Our study differs from these in that the air measurements were conducted within residential neighbourhoods.

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The measurements that we conducted were located in the town of Erie, Colorado, which is located about 25 km east of Boulder and 40 km north of Denver, and has approximately 28,000 residents, and also slightly north near the town of Longmont. Erie can be considered a small, suburb or bedroom-community of both Boulder and Denver, and has been attracting young families due to its location outside of major cities and more affordable housing. This study was motivated directly by concerns of residents, who worry that emissions from nearby wells could be leading to detrimental health effects for themselves and their children with repeated, long-term exposure at their homes.

Q: Your paper states that elevated levels of non-methane hydrocarbons (NMHC) can lead to detrimental air quality, and that exposure to NMHCs such as benzene can have health impacts – why is this, and what sort of effects might we see as a result of exposure?

A: From an air quality standpoint, one of the primary reasons we are concerned about emissions of NMHCs is that they are precursors to ground-level ozone formation. Ground-level, or tropospheric, ozone is a pollutant that is regulated in the United States by the EPA, and well as by many other developed countries around the world. Ozone does have a natural background level of approximately 30 – 40 parts-per-billion (ppb) for the Northern mid-latitude regions, however, elevated levels of ozone are a concern as they can cause severe respiratory distress in humans and animals, and have negative effects on vegetation, including reduced crop yields. Ozone is also the primary component of photochemical smog, as we have seen so dramatically demonstrated in large megacities such as Los Angeles and Mexico City, where ozone can reach well into the several hundreds of ppb levels during mid-day and lead to greatly diminished visibility. The Front Range region of Colorado, an area spanning from Denver to the north and northeast, has been designated a non-attainment area for ozone since 2007, regularly exceeding the 75 ppb regulation imposed by the US EPA.

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Aside from leading to ozone formation, some of the NMHCs present in fugitive emissions, or used industrially in support of O&NG operations, can have negative health impacts directly. Benzene is one such compound that is relatively well-known due to its carcinogenicity. Other compounds, such as toluene, ethylbenzene, and 1,3-butadiene, are also considered air toxics. The EPA and the World Health Organization (WHO) have established guidelines for chronic exposure to benzene. Chronic exposure to ambient levels of 1.7 µg/m³ increases one's chance of developing cancer to 1 in 100,000.

Q: How did you carry out your research, and what instrumentation/equipment was used in the process?

A: The measurements conducted in Erie were 6 liter whole air samples collected into stainless steel electropolished canisters. These operate by pulling a vacuum on the canister until it is below ambient pressure, and then re-filling with ambient air at a low flow rate over periods of 3 or 24 hours. We scrub the incoming air for ozone to minimize additional chemical reactions occurring in the canister after sampling. The air collected in the canisters is then analysed on a gas chromatograph with both flame ionization and mass spectrometric detection for compound identification. We collected a total of 30 air samples distributed amongst 7 private residences within Erie and slightly to the north near Longmont. In our analysis, we compared these measurements with similar measurements conducted by the Colorado Department of Public Health and Environment at their monitoring sites in Platteville (located within the O&NG field) and downtown Denver. Their sampling and analysis protocol is very similar to ours.

Q: You mention that there has been an increase in drilling activities near to residential and municipal locations. Why do you think this is happening?

A: Drilling operations for oil and gas have traditionally been performed in rural locations, however, this dynamic has been changing in recent years, leading to situations where O&NG operations and residential/municipal development are in close proximity, or even sharing the same plot of land. The reasons for this are primarily two-fold: urban/suburban sprawl is now stretching into pre-existing O&NG fields and new technologies allow O&NG extraction from previously inaccessible deposits that may be located in these populated areas. In Colorado, for example, drilling in the Front Range first began in 1862, and development of the Denver-Julesburg Basin (in the Denver/Boulder area) began in 1881. At that time, the oil and gas fields were quite remote from populated areas. In 1880, the population of Boulder was 3,070, Longmont was 773, and Erie had 358 residents. The town of Platteville did not yet exist, nor did many of the towns that we often hear about in Colorado in news about O&NG operations near homes. Denver had a population of only 36,000 in 1880, dropping to 11,000 in 1890 after the first gold boom died down. Since that time, urban and suburban sprawl has lead to more people living outside the major cities, including in the O&NG basin, in search of more affordable housing. Many new homeowners here, especially those relocating from other states, are unaware that surface rights and mineral rights are owned and sold separately and that the vast majority of home sales do not include the mineral rights.

The second issue is that new technologies (such as hydraulic fracturing) have allowed O&NG extraction from shale and tight sands formation, and horizontal drilling allows for extraction from underneath existing homes and businesses with the wellhead located hundreds of meters to several km away. This has made it both physically and financially feasible to access these previously undeveloped reservoirs.

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Q: Current literature on the risk of exposure to NMHC can be contradictory – can you explain the thinking behind this?

A: The very simple answer to this is that currently are no long-term health studies investigating the impacts of chronic exposure to O&NG emissions. Certain compounds, such as benzene, do have published exposure thresholds from the WHO and the US EPA, however, the majority of NMHC compounds do not, nor do these thresholds account for co-emission and exposure to multiple different compounds at the same time. OSHA regulations were developed to protect workers from occupational exposures of known compounds, and are not appropriate to cite for this particular situation. An added complication is that the emissions composition and volume can be vastly different during the drilling phase, the fracturing and flowback phase, and the regular production phase. Generally, during drilling and fracturing/flowback there are higher, more acute emissions, but in a very active field there may be numerous drilling rigs operating at any given time. Thus, there have only been very few health studies published to date assessing exposure risks from these operations, and I would refer the interested reader to works by Lisa McKenzie and Theo Colborn for more information.

Q: What were the results of your study, and did they correlate with existing data?

A: Our study largely corroborated a growing body of evidence that these shale basins constitute a large area source for NMHCs that act as ozone precursors. The highest ambient levels were found in the center of the O&NG field (Platteville), however Erie/Longmont, on the western periphery, also had strong enhancements in the light alkanes (ethane, propane, butane, pentane). For example, Erie/Longmont had 80 times higher average butane values than regional background values, whereas butane in Platteville was enhanced by a factor of 400 over background. By using propane as a tracer compound for O&NG, and acetylene as a tracer for vehicle/urban emissions, we were able to show that O&NG emissions accounted for approximately 73% of ambient benzene in Platteville whereas vehicle/urban emissions contributed 72% to ambient benzene levels in Denver. It should also be noted that ambient benzene levels were nearly double in Platteville than in downtown Denver. Finally, by using some previous measurements that had been conducted in this region over the last couple of decades, we were able to provide some preliminary indications that ambient alkane levels in Boulder, relatively removed from the O&NG field, have been increasing and that there has been a shift towards a greater contribution from O&NG emissions to those ambient levels.

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Q: Can anything be done to mitigate the effects of NMHC in residential areas?

A: There are definitely ways to mitigate exposure to emissions, and to their credit, Colorado does have the tightest regulations on VOCs and methane in the US.

Some things that can be done include mandatory "green completions" of wells that capture any vented emissions within a closed system, low-bleed pneumatic valves, vapour capture systems, and tighter seals on equipment that is known to leak such as thief hatches on condensate tanks. There are also significant benefits to investing in higher quality infrastructure for gas collection as we have seen in comparing emissions from Utah and Colorado. Colorado has a vast network of underground pipes to collect and transport gas to central distribution facilities, eliminating the need for individual truck collections and minimizing fugitive emissions to the air from the pipes. In contrast, Utah, where much higher methane and NMHC emissions have been measured, has above ground piping and numerous individual, isolated wells that require routine truck collection, thereby increasing the instances of unintentional venting and increasing emissions from heavy truck traffic. Finally, strict well-abandonment procedures should be in place to prevent gas leakage from unproductive, abandoned wells. In this case, there are lessons to be learned from the urban oil and gas fields in the Los Angeles Basin, where several dangerous incidents have occurred relating to poor well-abandonment practices.

Gas wells near homes in Erie, Colorado, USA.

Q: Finally, drilling for natural (shale) gas is taking off in Europe at the moment. Should we be concerned for our health?

A: It is really up to the individual to decide what their own personal comfort level is and to educate themselves on what is known about the risks associated with living near O&NG operations and what regulations are in place for where they are living. It is beneficial from an air quality and health standpoint, and from a climate standpoint, to require best practices according to the best technology available including green completions for drilling operations. It is also prudent to proceed with caution, and ensure that safeguards are in place to protect the public and the environment from all possible risks, as it is generally much harder to remediate than it is to prevent.

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For reliable and continuously operating exhaust gas analysis with repeatable and representative measurement results it is essential to have an efficient and tailored sample handling system. This is often a complex task with several steps of conditioning equipment. Only the correct choice and the right sequence will lead to continuous and trouble free operation of the whole system, ideally with minimum maintenance and of course cost effective - for the system integrator as well as the operator.

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The first critical step in the sample handling sequence is the gas sampling probe - usually a heated gas sampling probe that removes dust particulates and other solids and avoids condensation of water vapour. The heating avoids corrosion as well as chemical change like wash out of water soluble gases. A consistent and homogenous temperature above the dew point is essential. The basic models of the JES series sampling probes offer a wide range of sampling tubes, heated sampling tubes and pre filters. Completed by an extensive range of built in options like flange size, filter material, process cut-off valves, back purge and calibration systems the sampling probe can be tailored exactly to any application.

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The further conditioning of the sample gas happens usually in the analyser cabinet. Standard components for this task are sample gas coolers for specific removal of condensate, condensate detection systems and fine dust filters for removal of remaining dust particulates. These components are protecting analysers from condensate and dust particulates and guarantee reliable measurements without cross-sensitivity caused by water vapour. Further necessary components are sample gas pumps and flow meters to set the correct flow rate for the analyser. JCT offers all components as single parts as well as turnkey solutions for sample gas conditioning. The JCL, JCC and JC series sample gas conditioners comprise all necessary equipment and avoid complicated and expensive single sourcing as well as mounting, wiring and tubing of the single components. Of course all units are self monitored and offer the highest safety for the analyser.

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